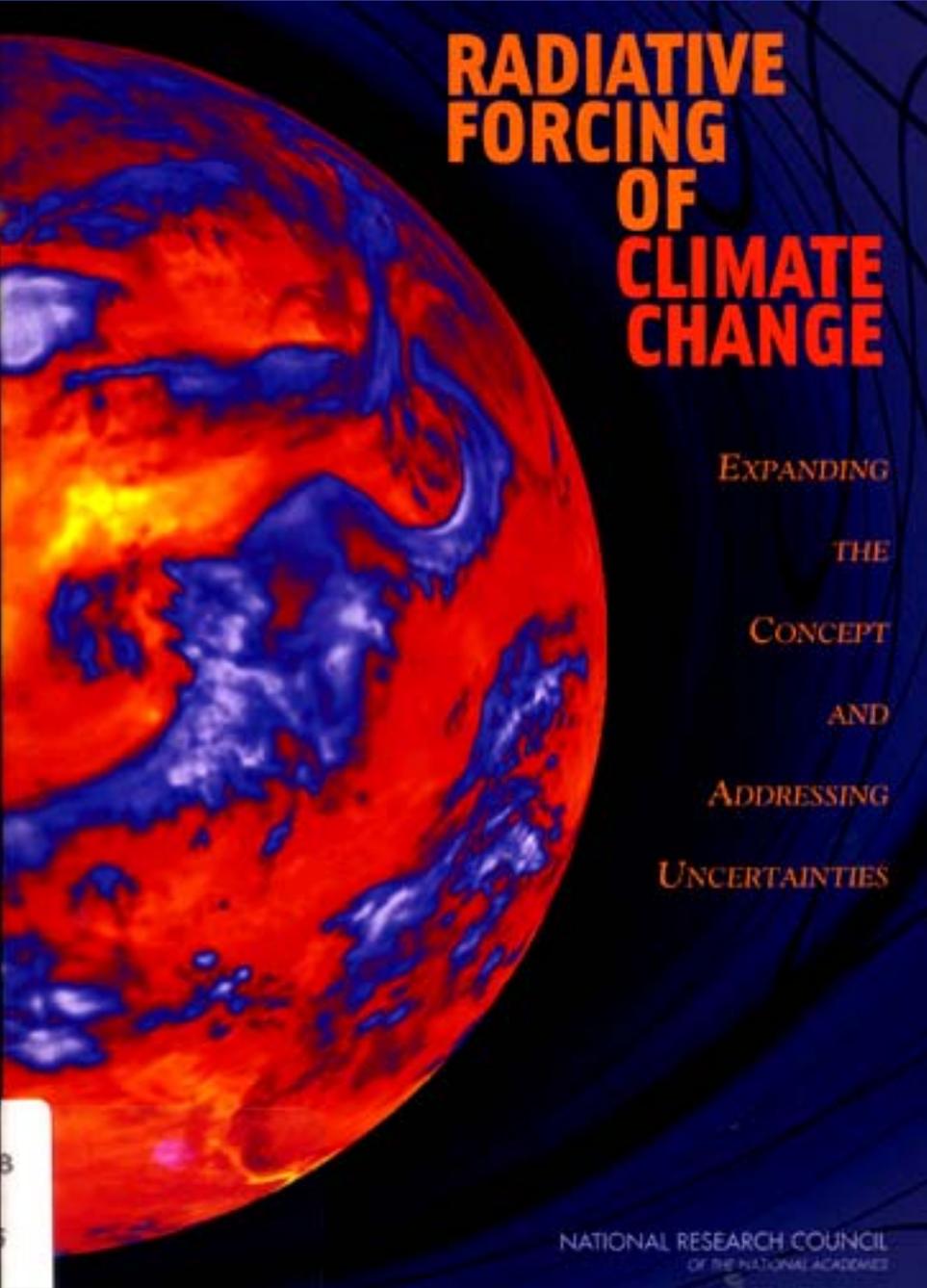


An overview of radiative heating profile in the atmosphere, and pathways to the future

Warren Wiscombe
Brookhaven Nat'l Lab
& NASA Goddard





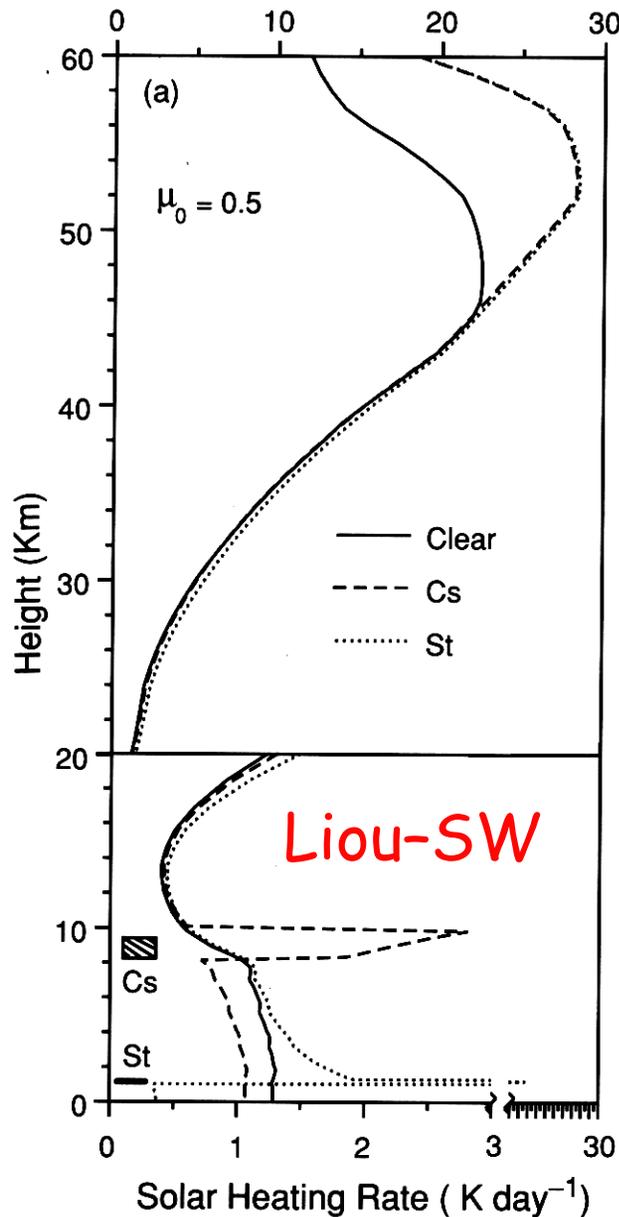
RADIATIVE FORCING OF CLIMATE CHANGE

EXPANDING
THE
CONCEPT
AND
ADDRESSING
UNCERTAINTIES

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

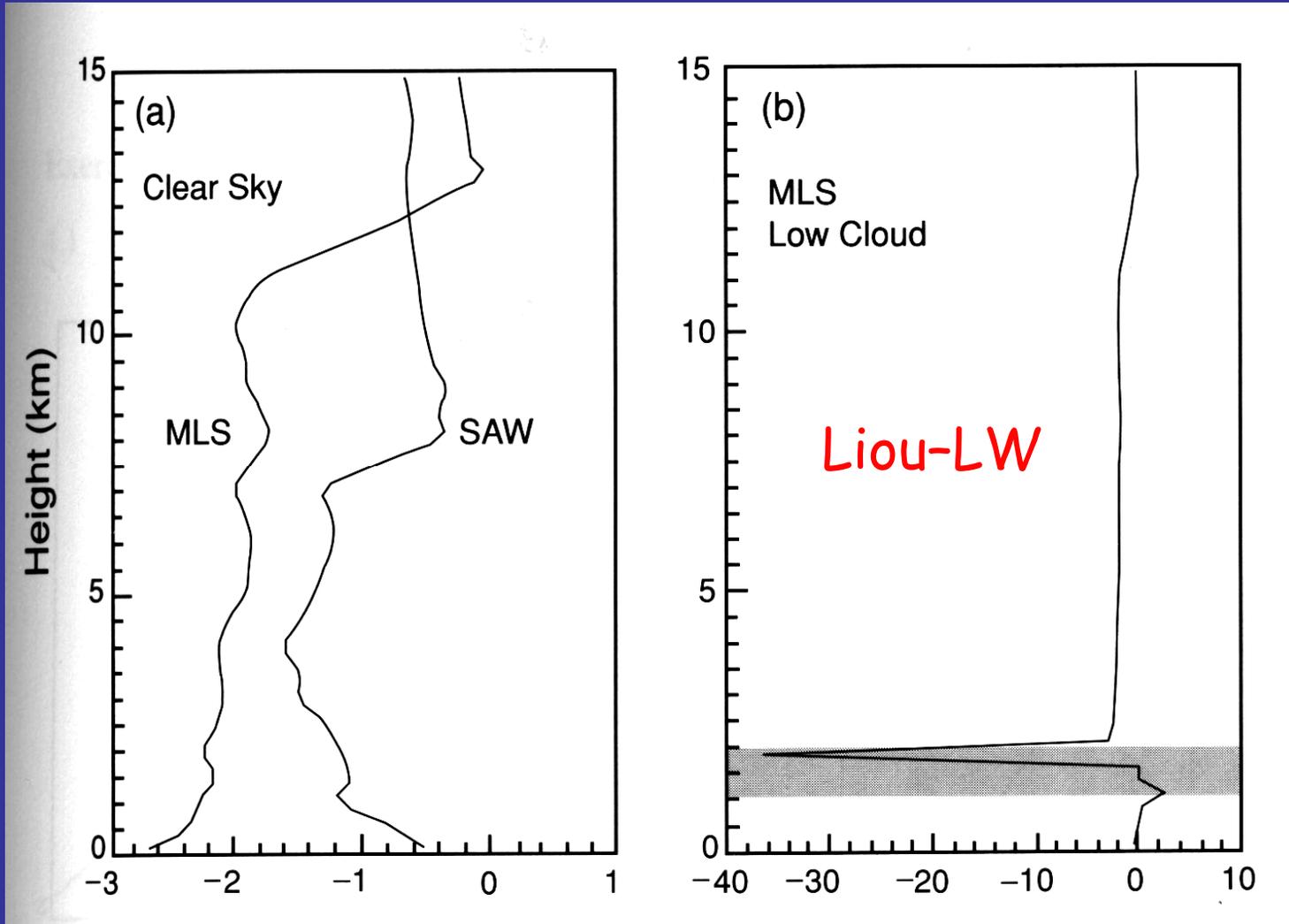
NAS report
recommends
expanding
concept of
radiative forcing
to vertical and
regional

What do our standard texts say about radiative heating profiles?

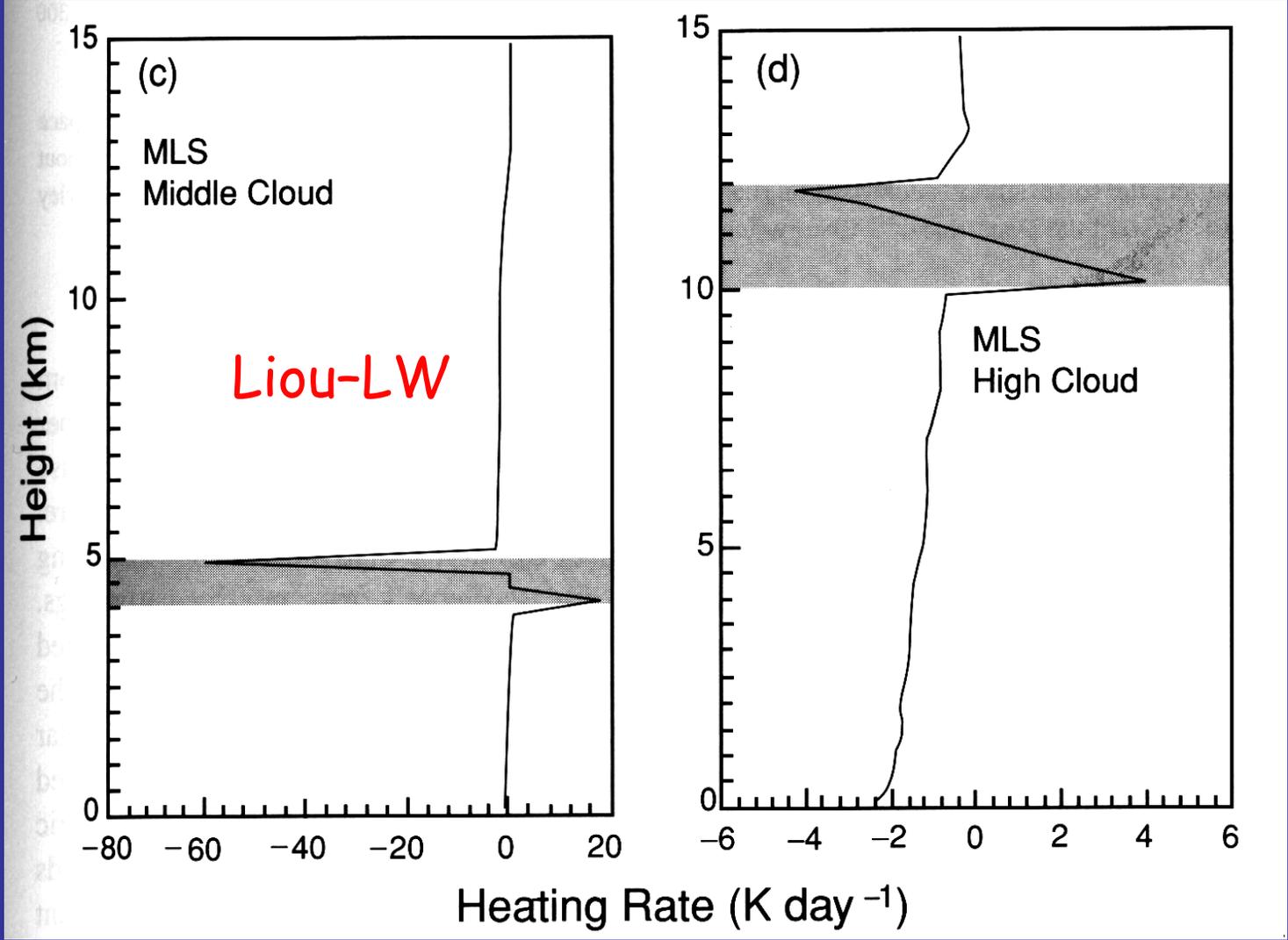


- Very little — handful of graphs and equations
- Almost no measurements
- Few comparisons with latent and other forms of heating/cooling
- Emphasis on shortwave

LW values are generally double SW in clear sky, much larger than SW near cloud top



Mid- and high-level clouds are whipsawed with LW cooling at top and heating at base



We spend most of our effort on the SW heating...

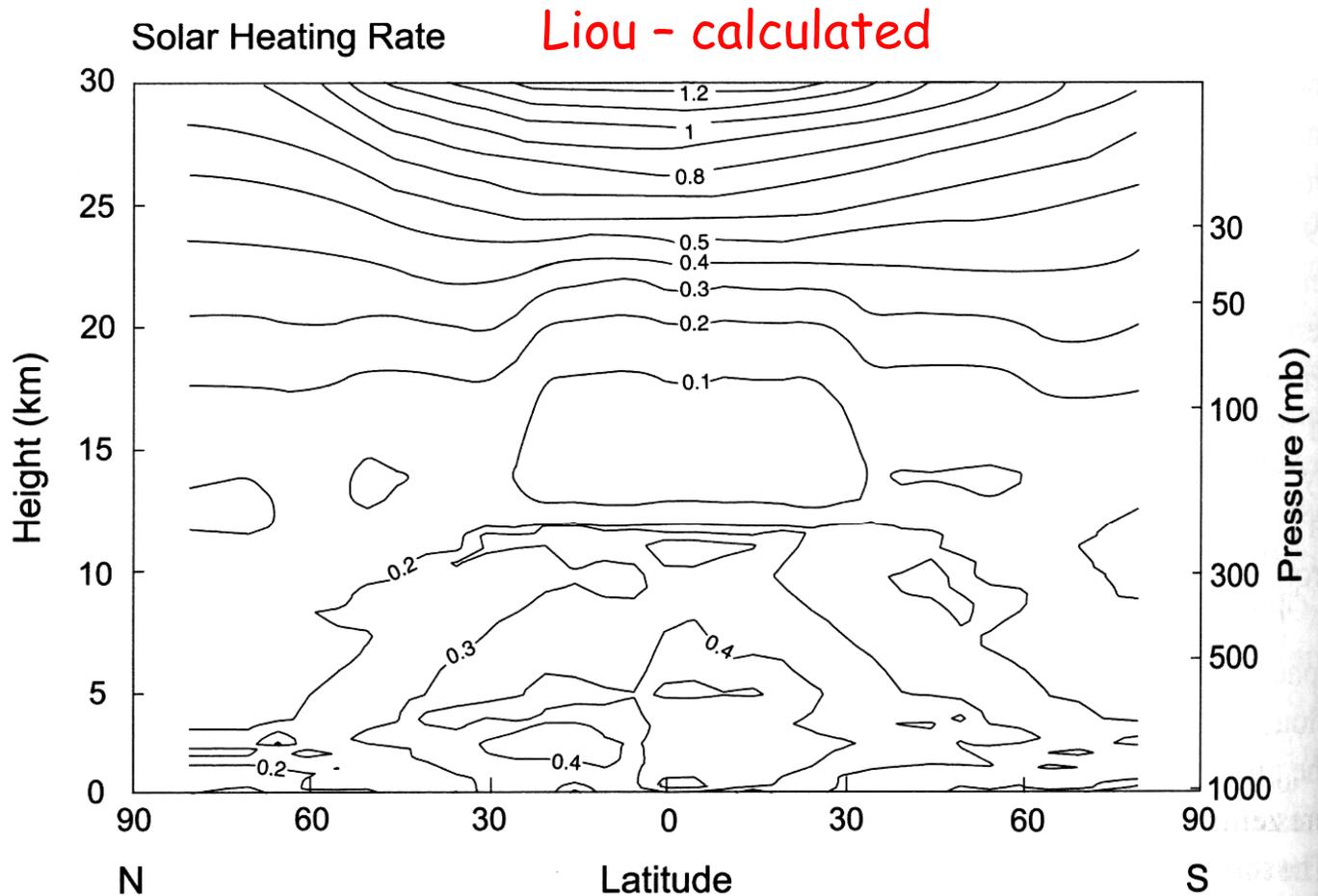
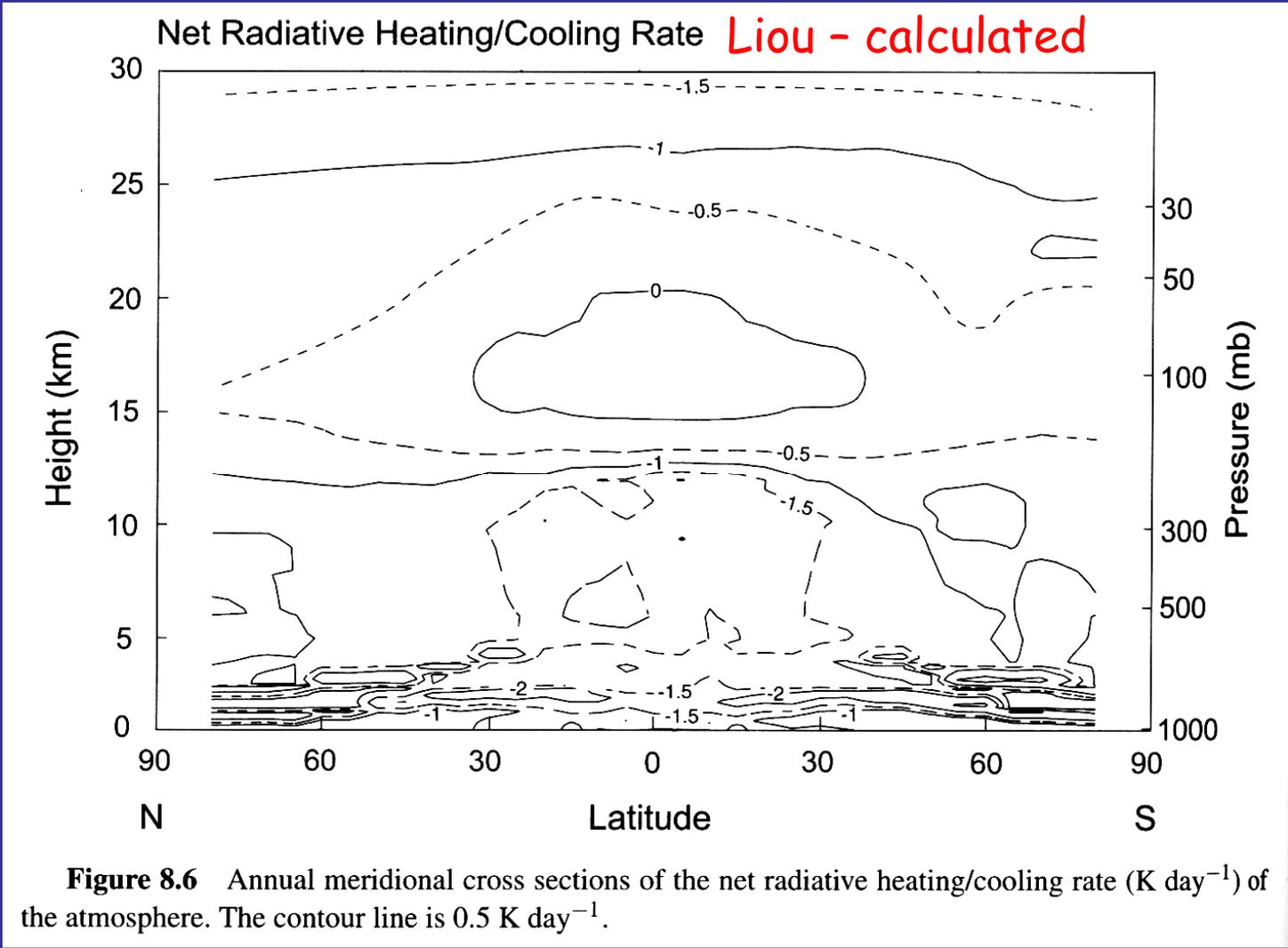
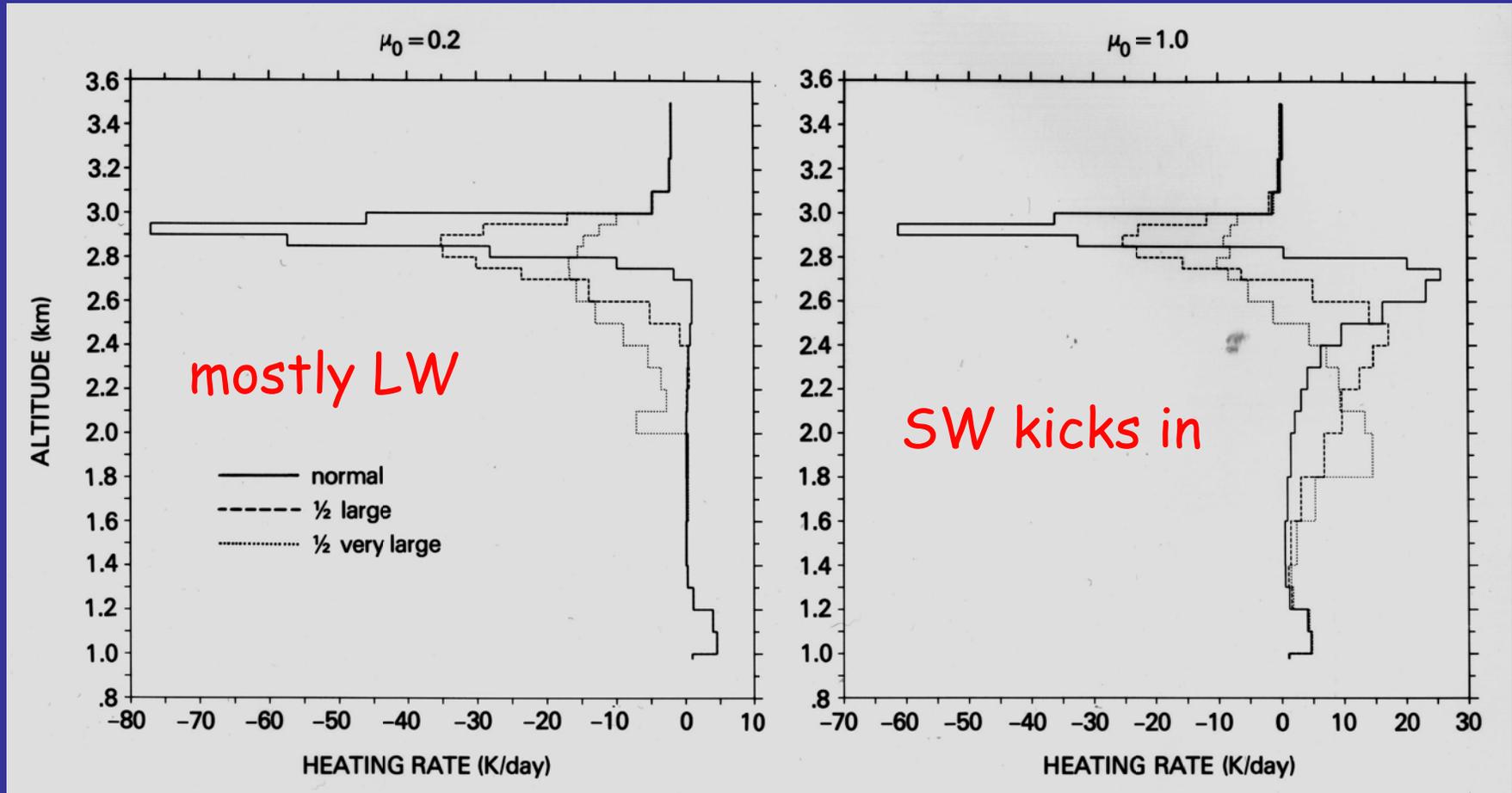


Figure 8.4 Annual meridional cross sections of the solar heating rate (K day^{-1}) of the atmosphere computed from a radiative transfer program using climatological temperature, cloud, gaseous, and surface albedo data. The input solar flux is 342 W m^{-2} . The contour line is 0.1 K day^{-1} .

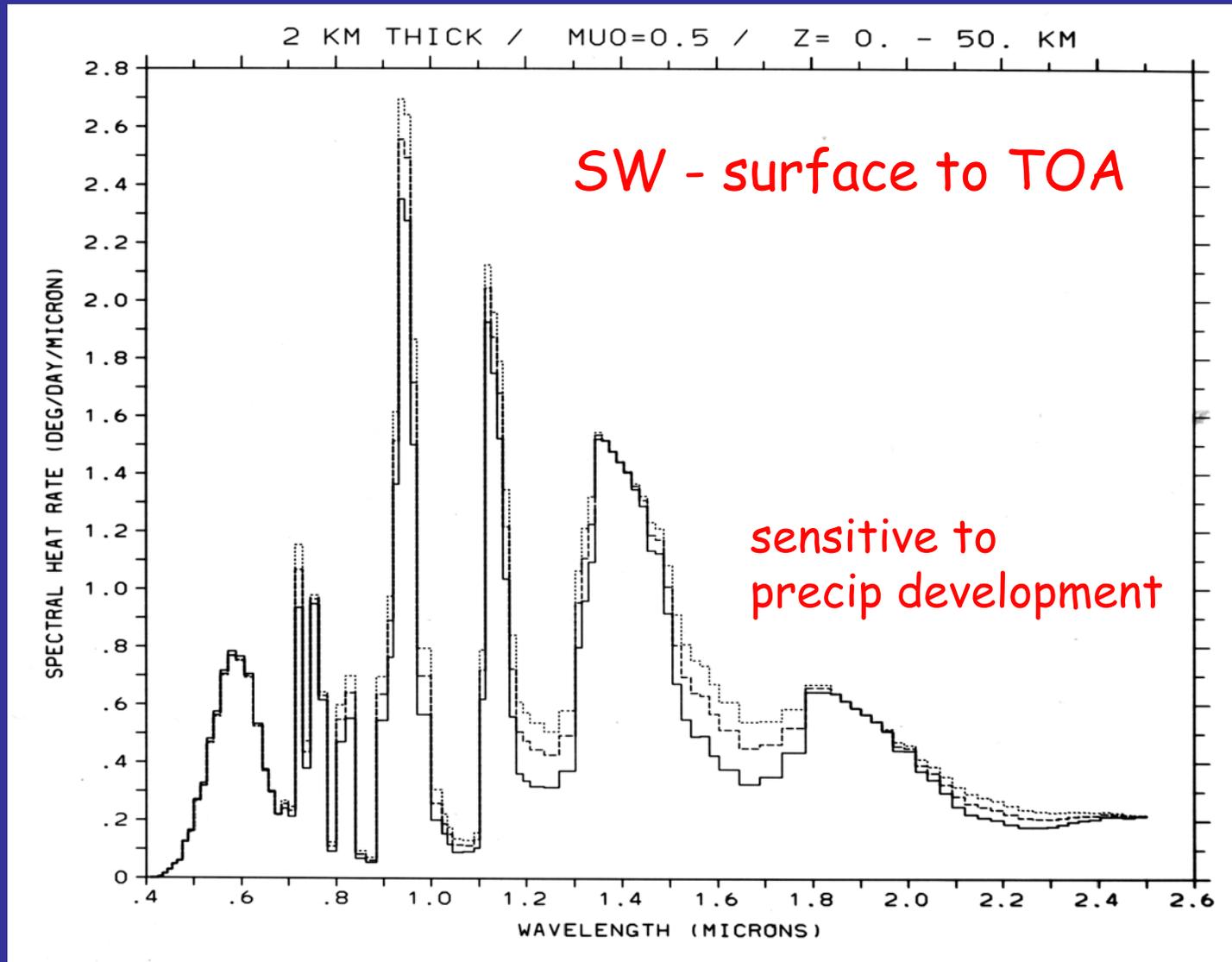
but actually the LW cooling dominates so that the net heating is negative almost everywhere



My ATRAD calculations from the early 1980s showed the tradeoff between SW and LW

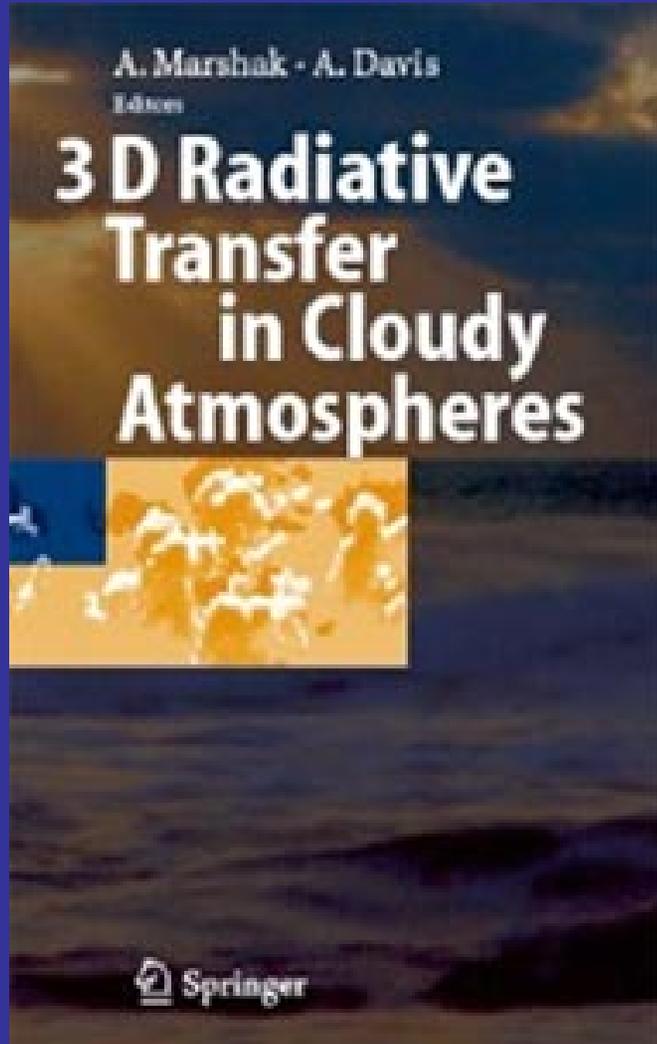


ATRAD produced NCAR-graphics plots of spectral heating for cloudy cases in 1970s



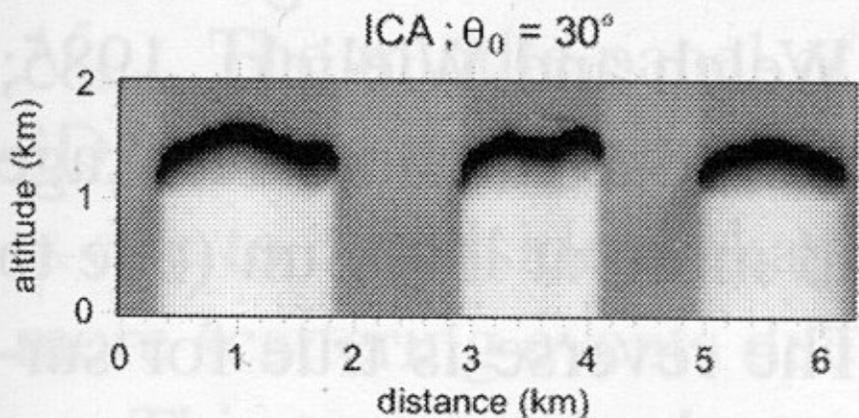
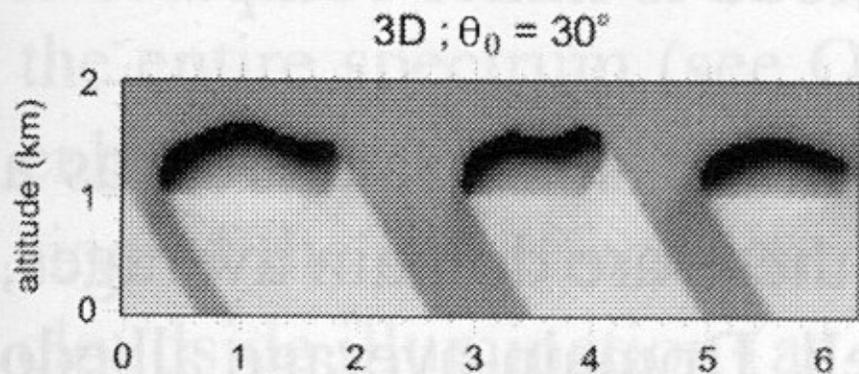
Now we leap to the present...

published 2005

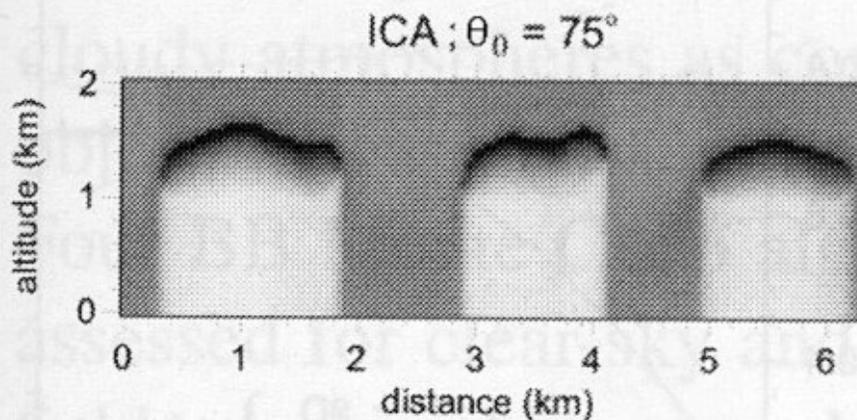
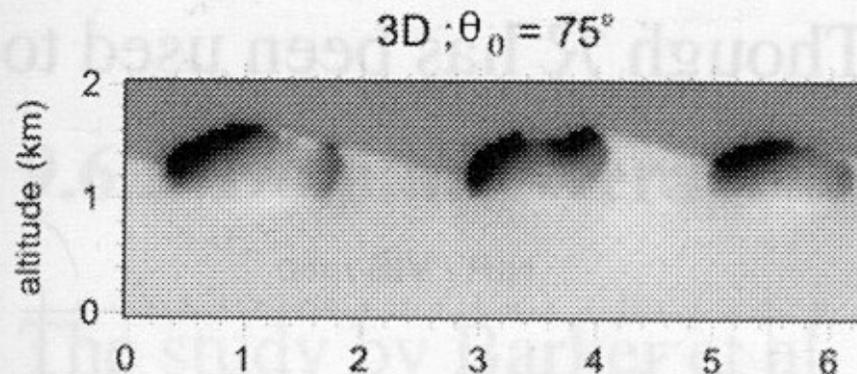


Barker 3D SW heating calculations for CRM clouds

from Marshak/Davis 2006

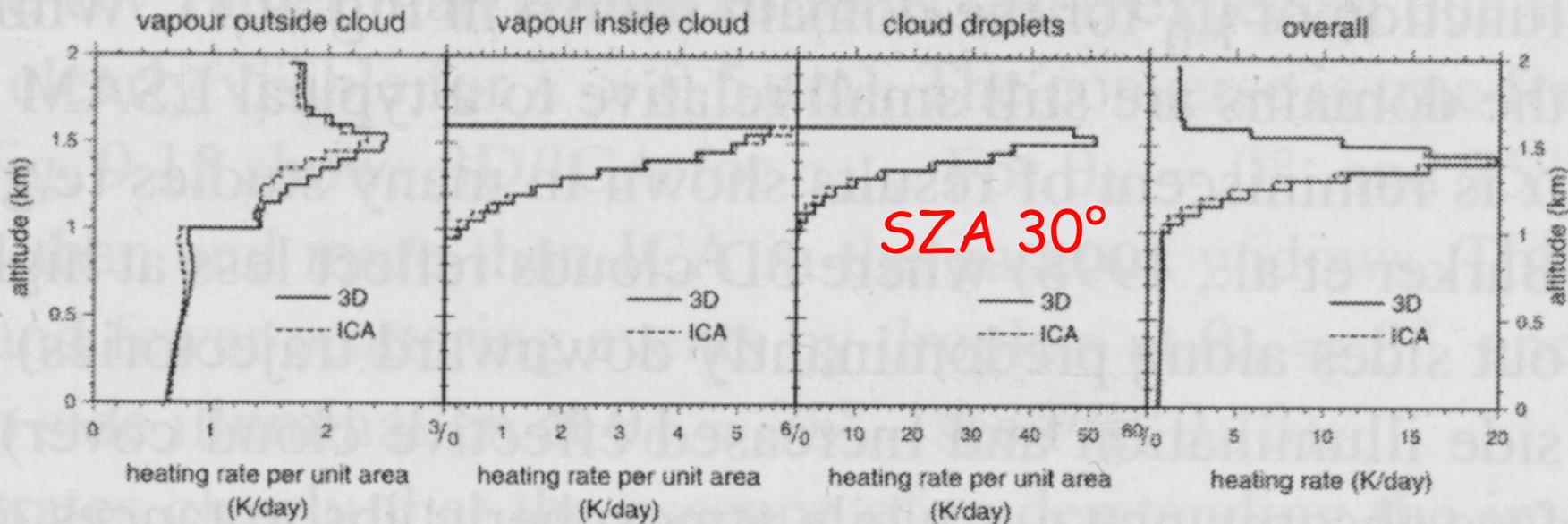
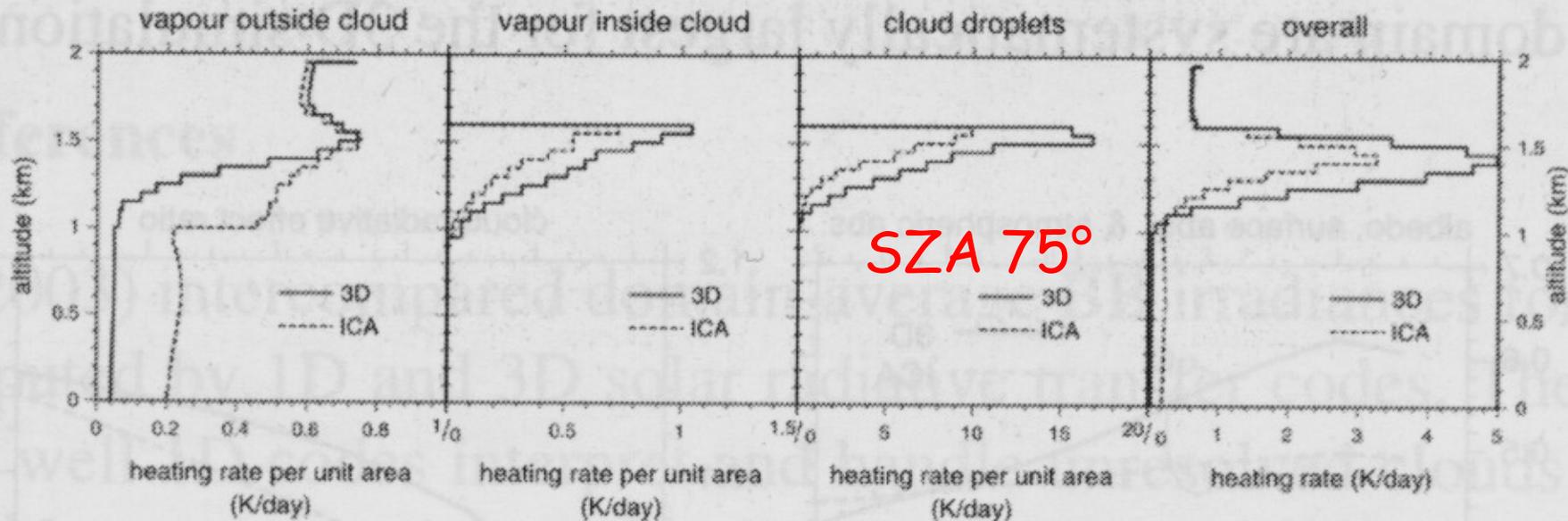


-1.5 -0.5 0.5 1.5
 $\log_{10} [\text{HR (K/day)}]$

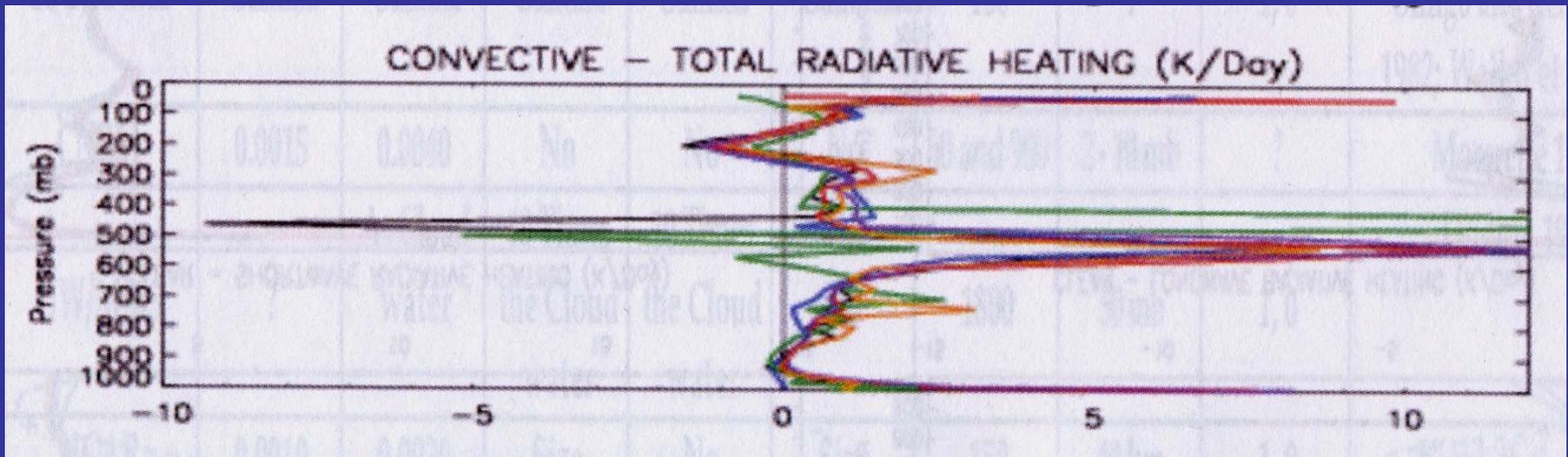
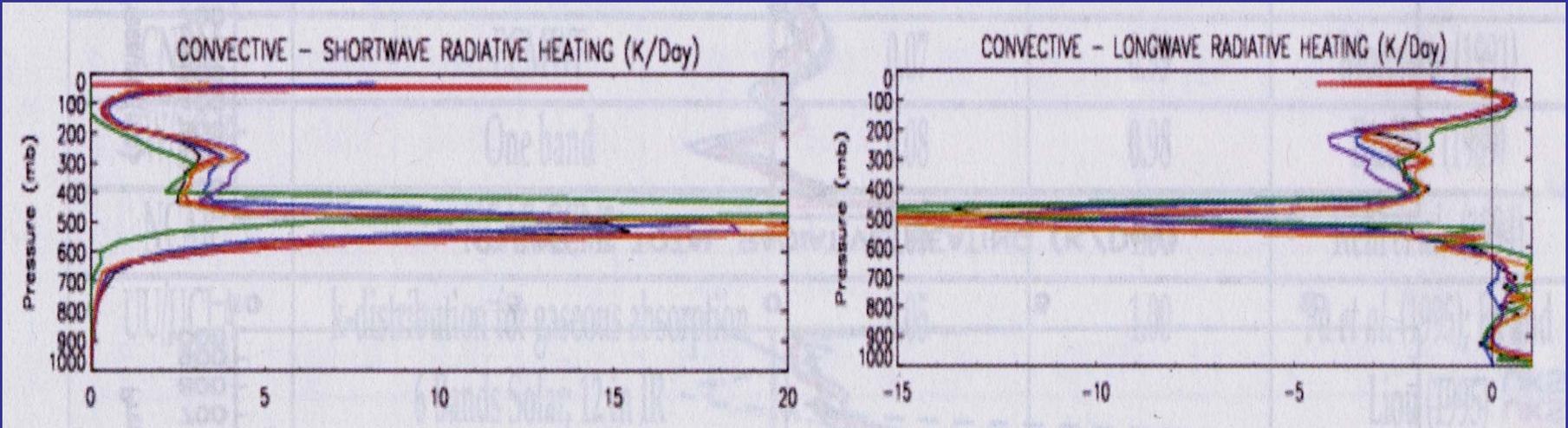


-2.5 -1.5 -0.5 0.5 1.5
 $\log_{10} [\text{HR (K/day)}]$

Domain averages for clouds from previous slide



Comparing many CRM rad'n models for a Goddard Cumulus Ensemble simulation (Tao)



Past attempts at measuring flux divergence

- Weinman -- top hat mean intensity meter
- Albrecht and Cox -- tried to make corrections for having single a/c and for "escaping photons"
- CAGEX
- Cess 5 sites
- ARESE I & II
- Niger



1D rad flux divergence related to mean intensity

$$\frac{dF}{dz} = 4\pi \alpha \left(\bar{I}_\nu - B_\nu(T) \right)$$

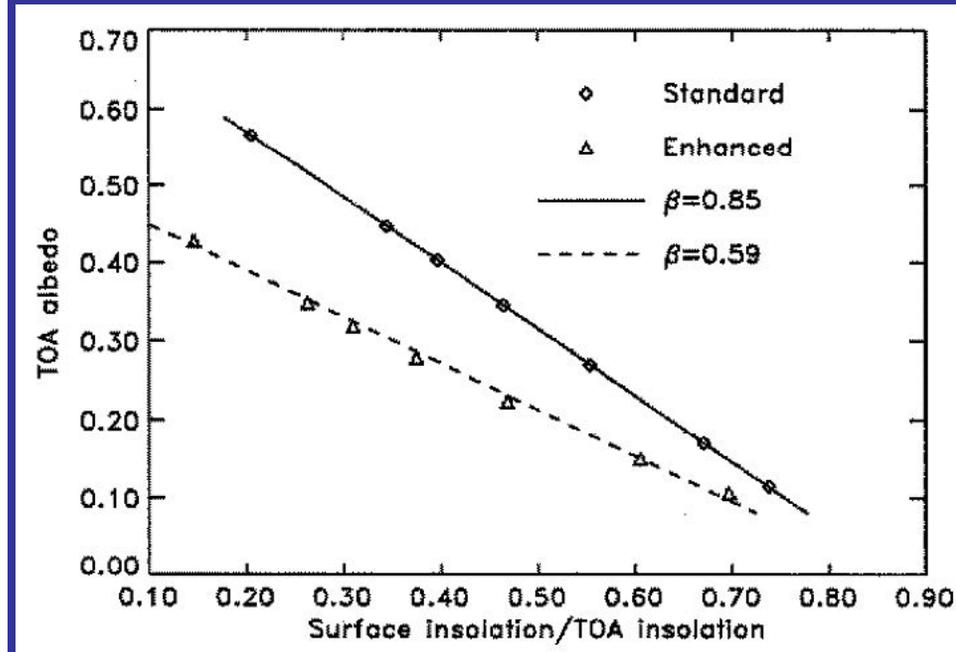
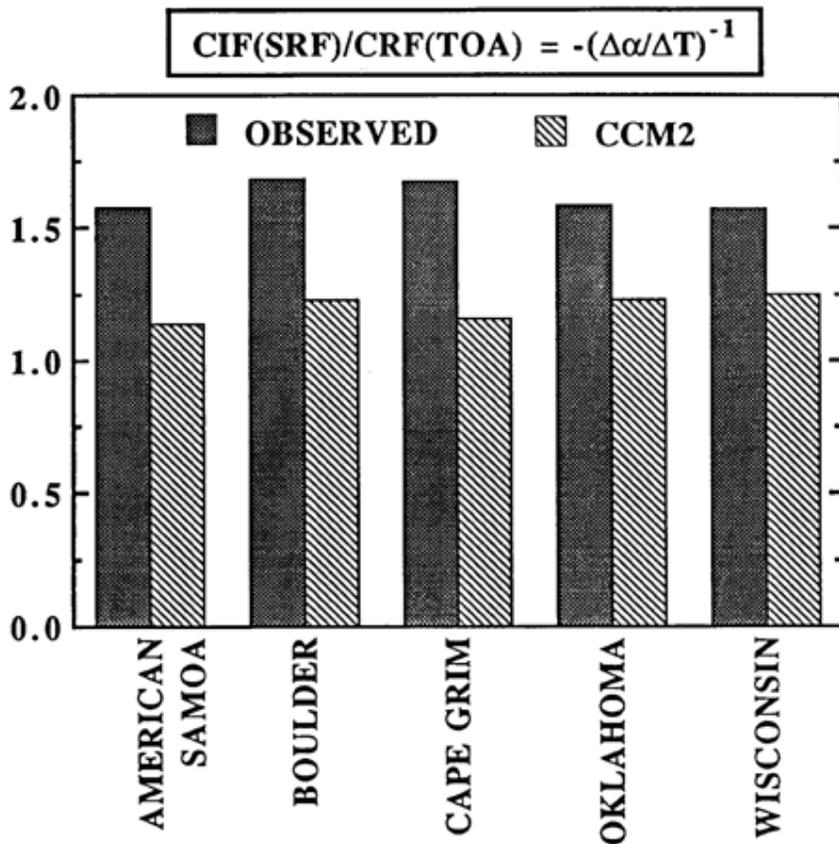
Thomas & Stamnes,
Eq 5.77

α = absorption coeff.

3D analogue?

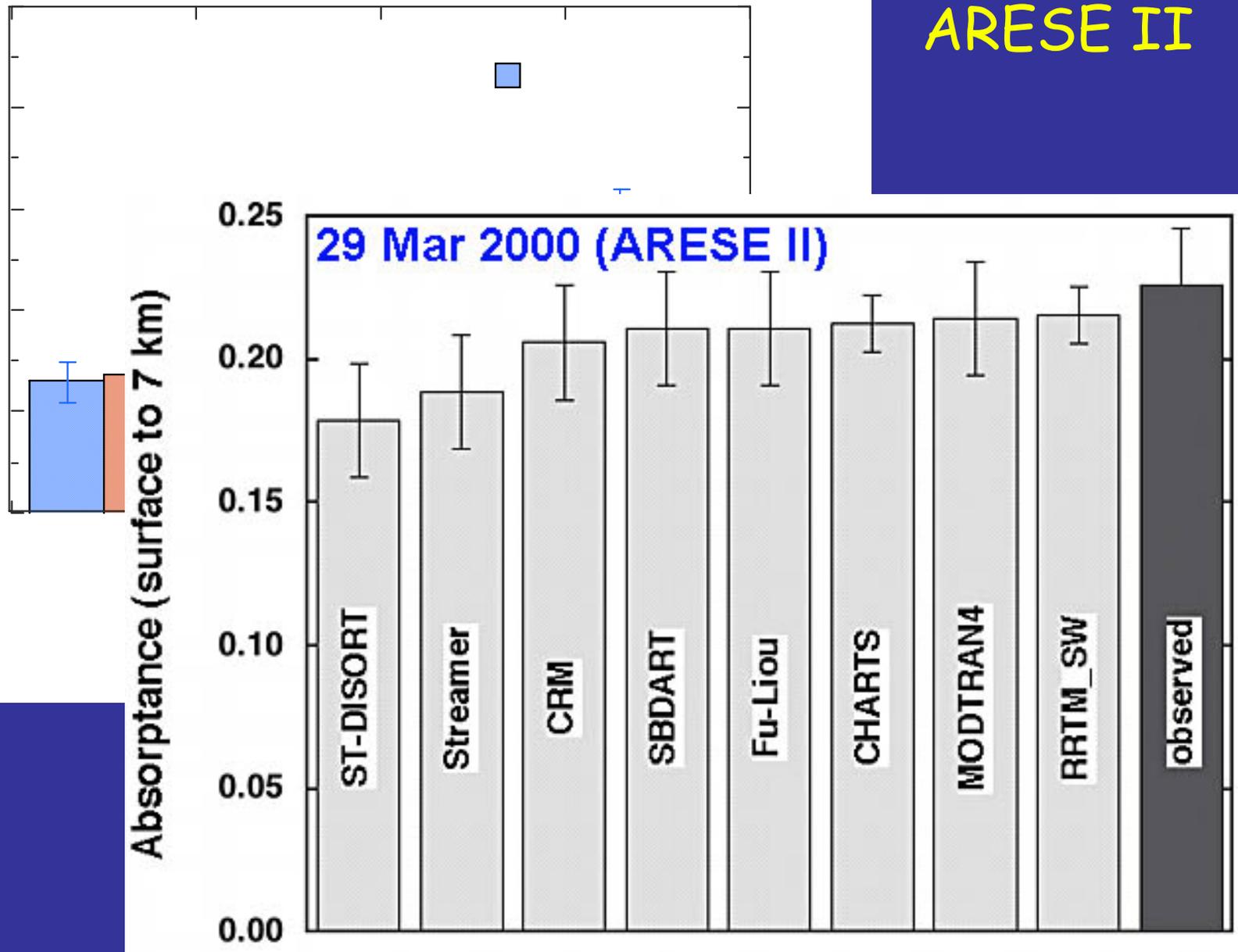
Does this idea have any future?

Cess: 5 sites and R_{TOA} vs surface transmittance

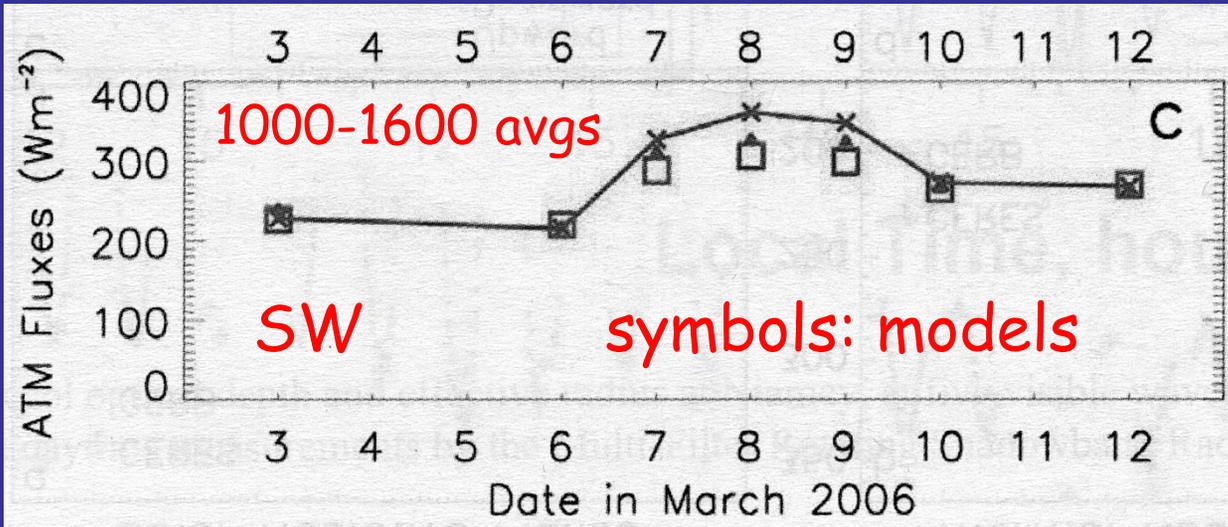


famous R vs T plot

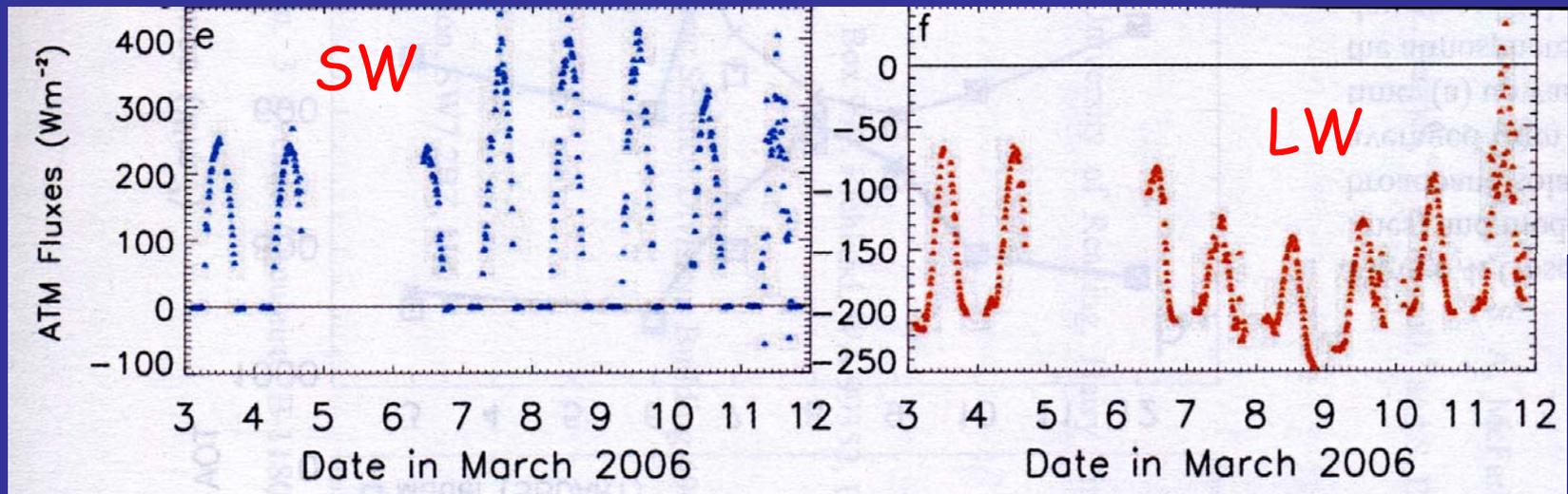
ARESE II



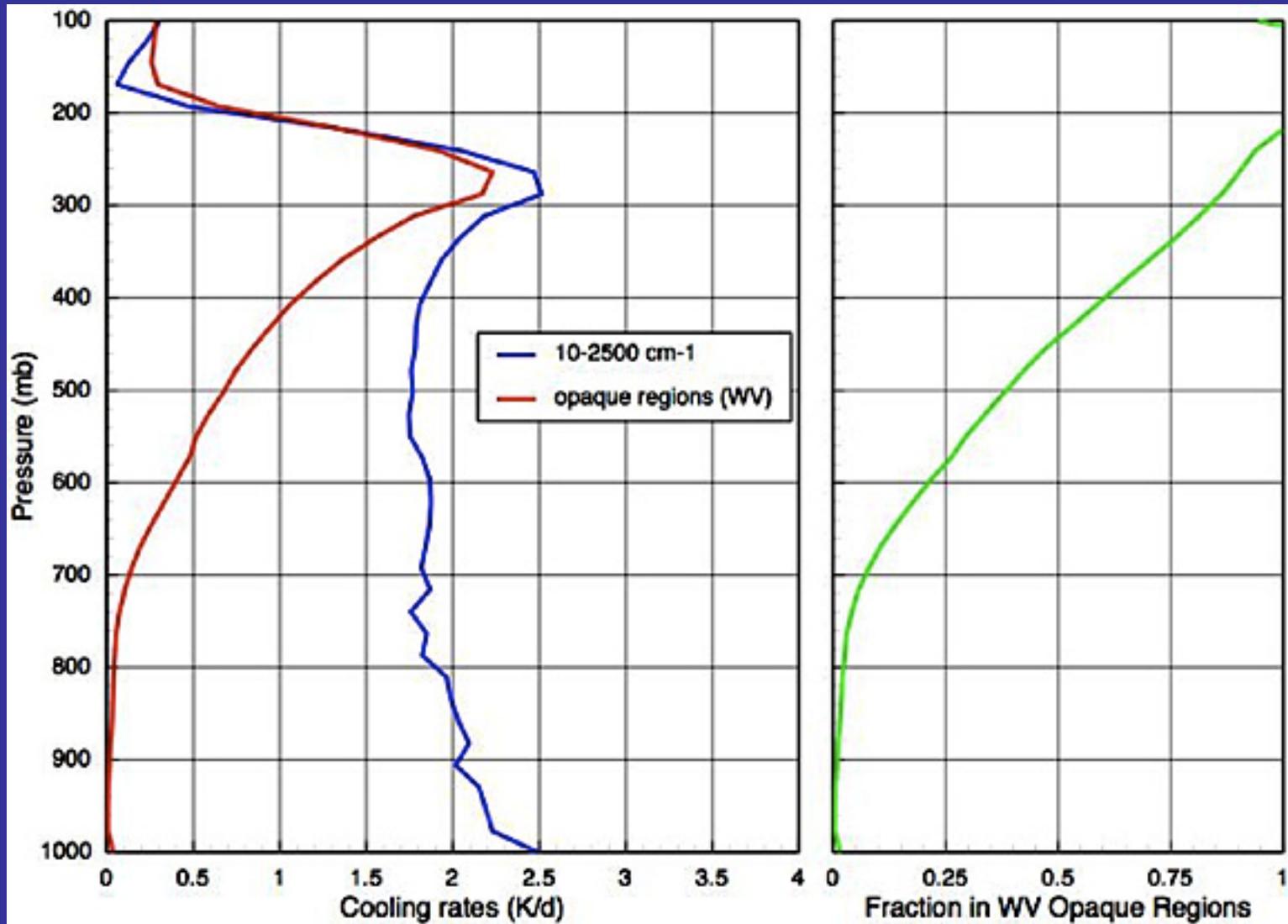
Niger: ARM Mobile Facility + GERB got first long-term radiative heating dataset!



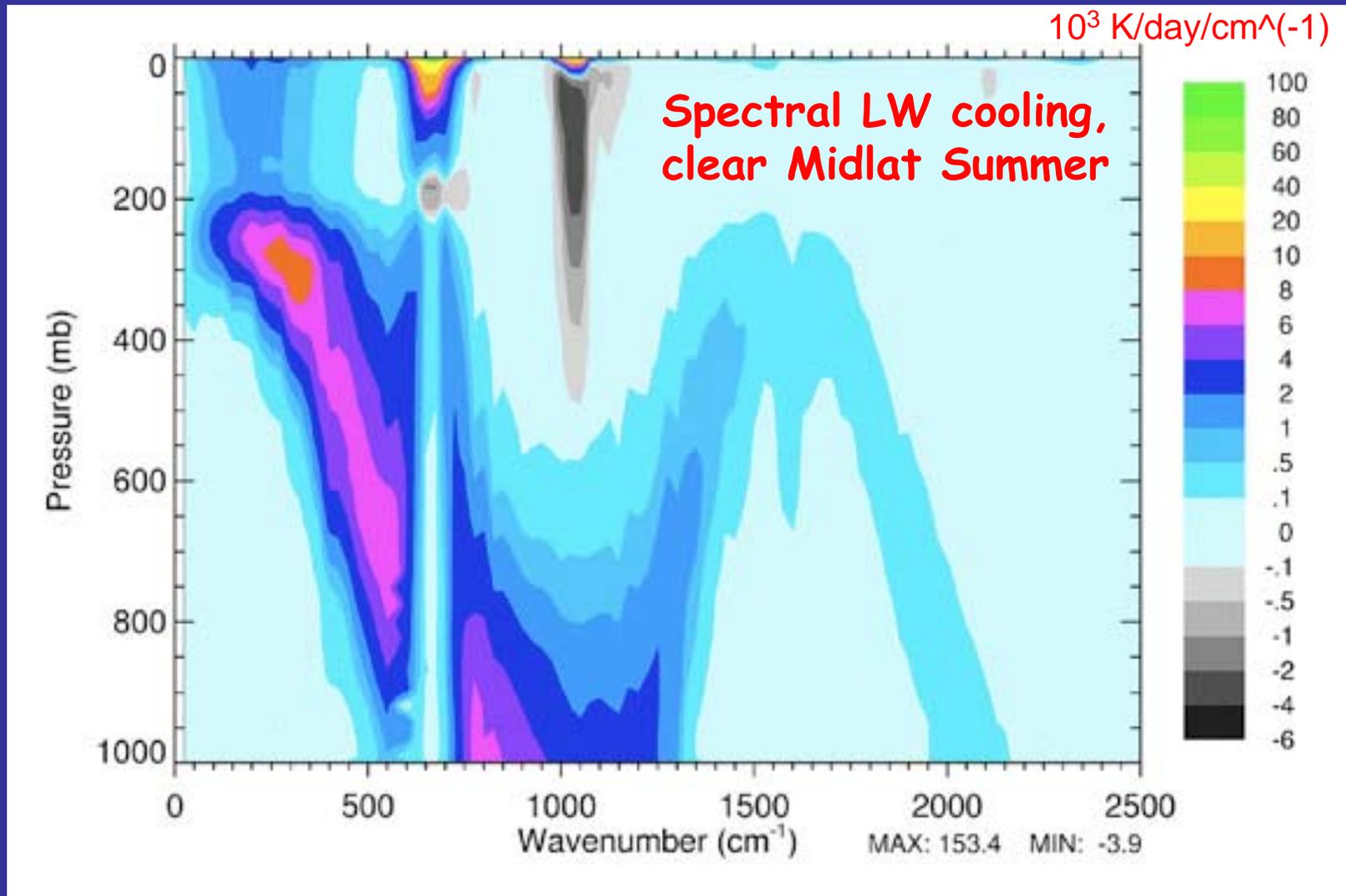
TOA to surface rad'n flux diffs vs. time



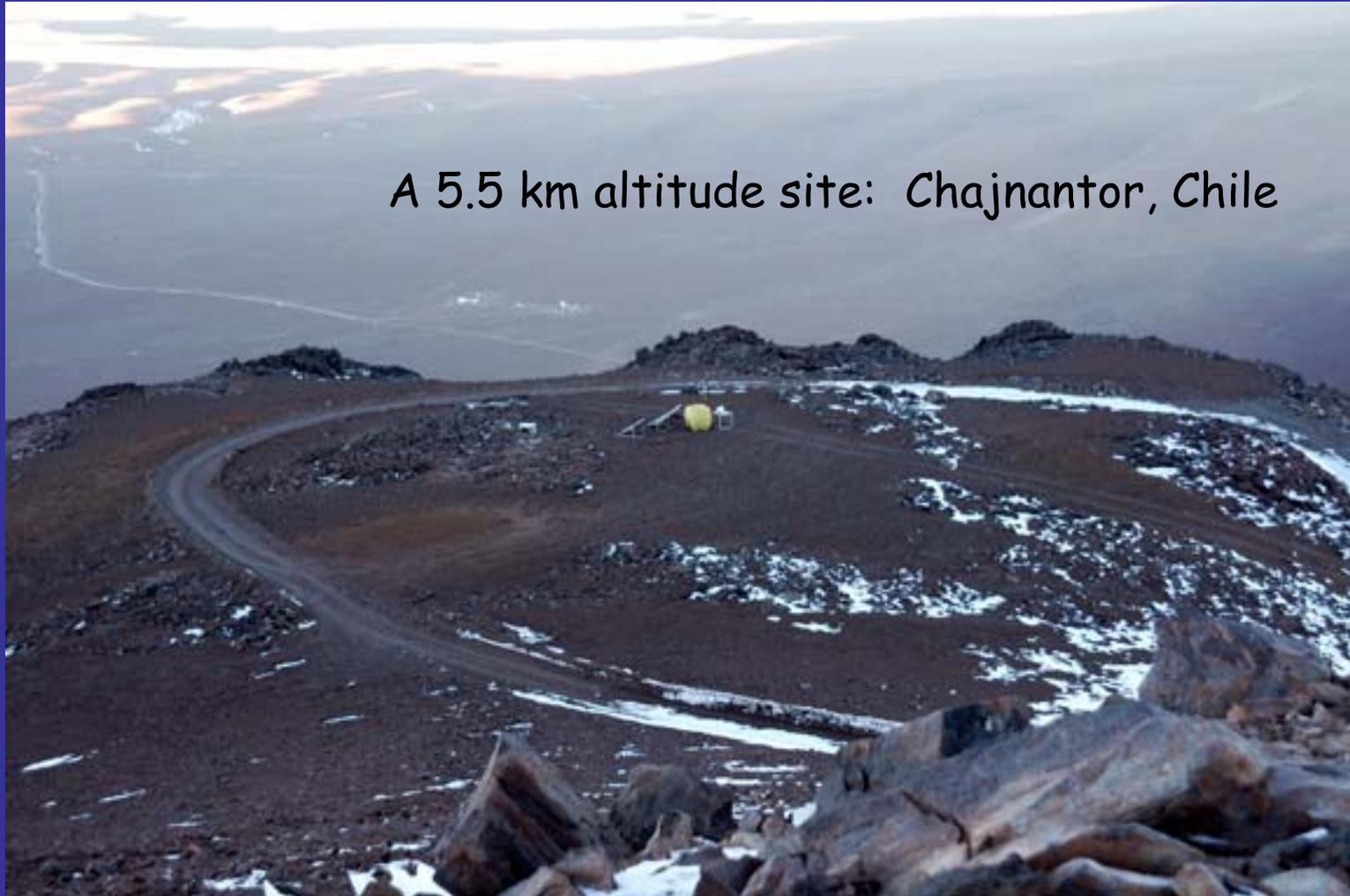
Far-IR dominates upper trop cooling rate



Clough plot shows where cooling is located spectrally – the far IR

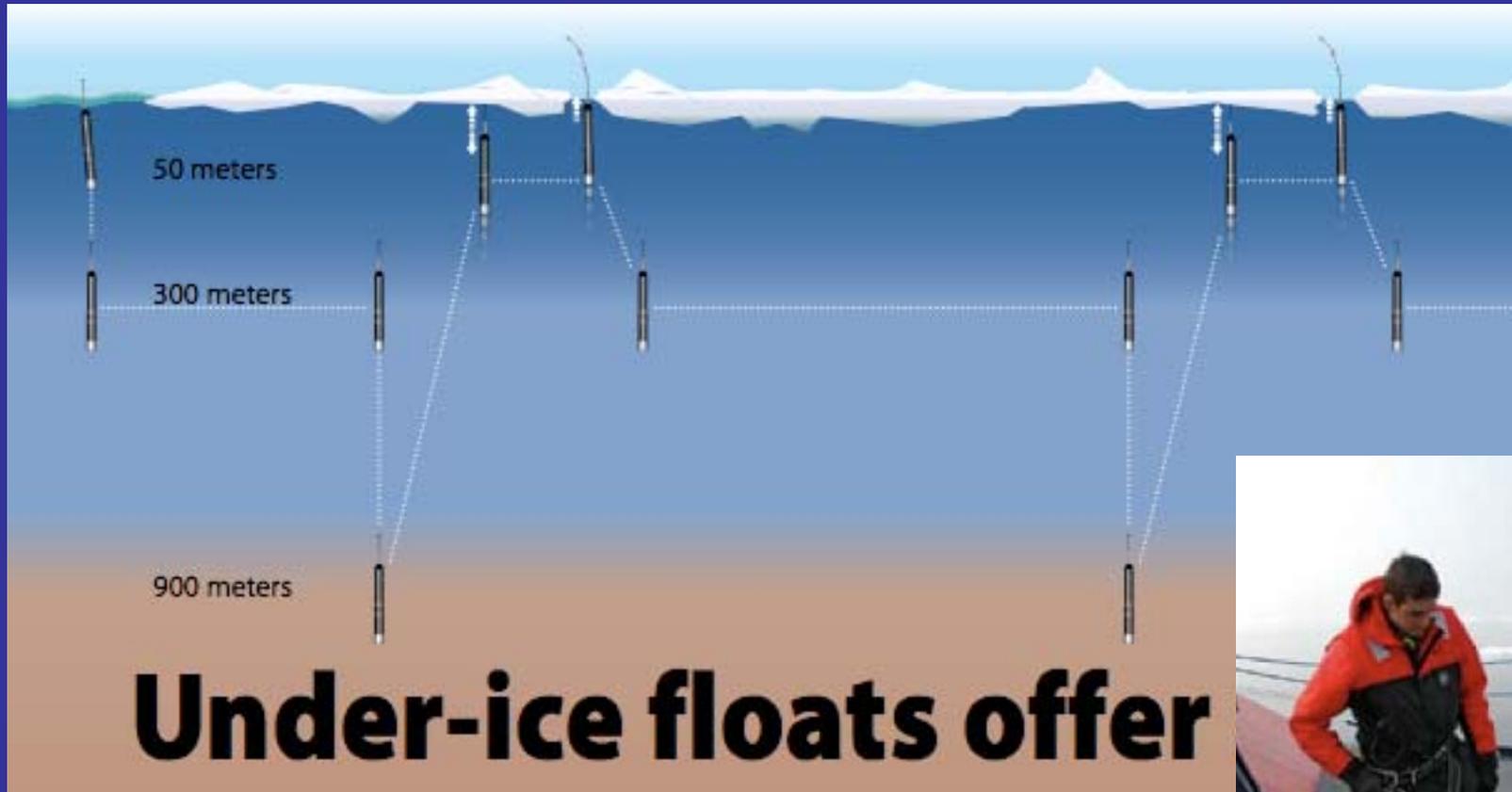


Future: Radiative Heating in Underexplored Bands Campaigns (Barrow, Chile, ...)



A 5.5 km altitude site: Chajnantor, Chile

Oceanographers are far ahead in profiling



A mooring to work under the ice

WHOI oceanographer Flamma Straneo deployed a mooring in the ice-covered Hudson Strait to measure the flow of water through this climatically significant gateway to the Atlantic Ocean.

Anchored to the seafloor 180 meters (590 feet) deep, the mooring line held a variety of instruments, including an experimental device called the Arctic Winch to obtain critical measurements in the top 50 meters (164 feet), where less-dense fresh water flows just below the ice.

The Arctic Winch, atop a red flotation sphere, periodically unspools a float with sensors to collect data as it rises toward the surface. It comes back down immediately when it hits ice or the surface, so that sea ice or icebergs don't sweep it away.



An upward-looking sonar measures the thickness of ice flowing over the mooring.



Straneo recovers a moored profiler, an instrument that moves up and down the line every two hours, measuring water temperature and salinity between 50 and 150 meters (164 and 492 feet).

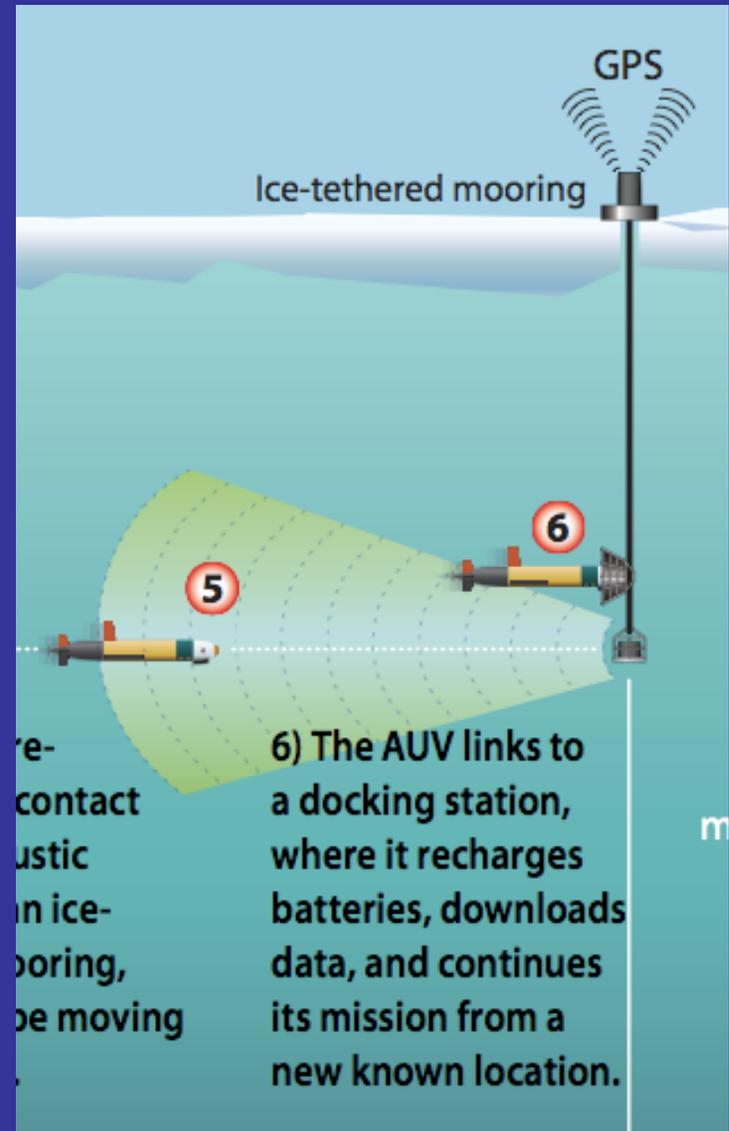


An acoustic Doppler current profiler uses sound waves to measure current speeds and directions.



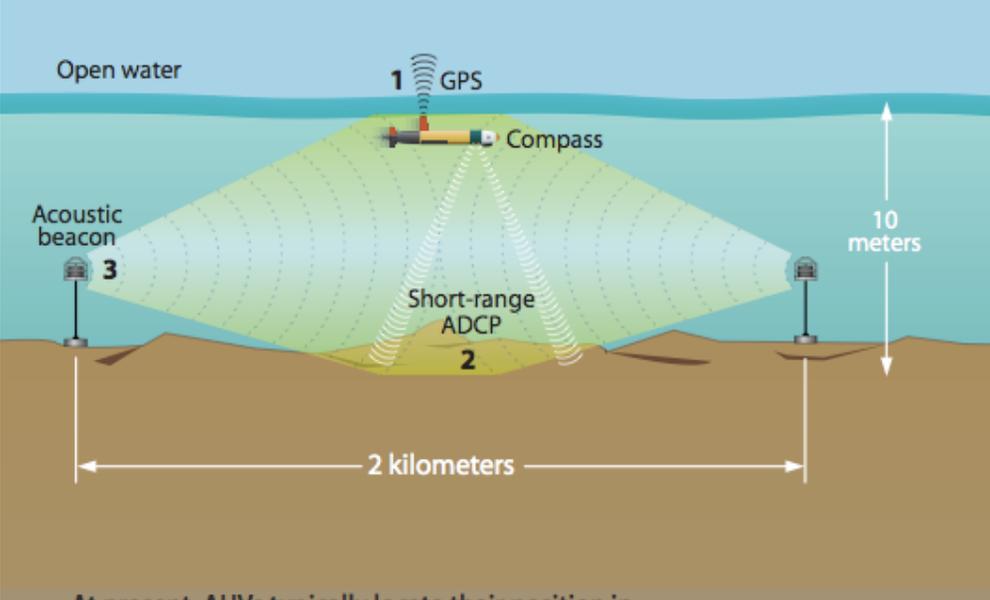
Underice profiling mooring

Autonomous underwater vehicle navigates by GPS, acoustic Doppler, beacons, and dead reckoning

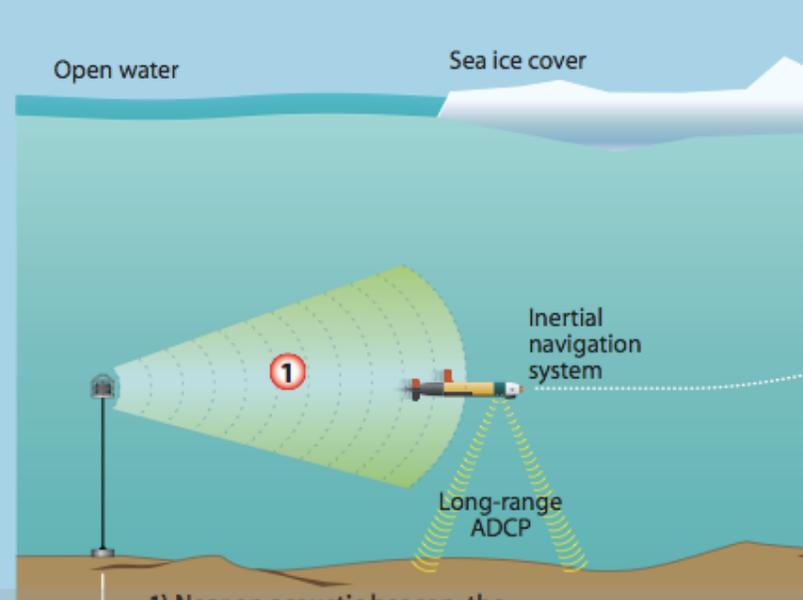


Autonomous underwater vehicle - 2

Navigating autonomous underwater vehicles (AUVs)



Stretching AUV navigation capabilities in the future



Autonomous abovewater vehicles



stacked UAVs (below, in,
above cloud)

balloon-launched
small UAV



Tethered (and un-) balloons underexploited



ditto for
tall towers

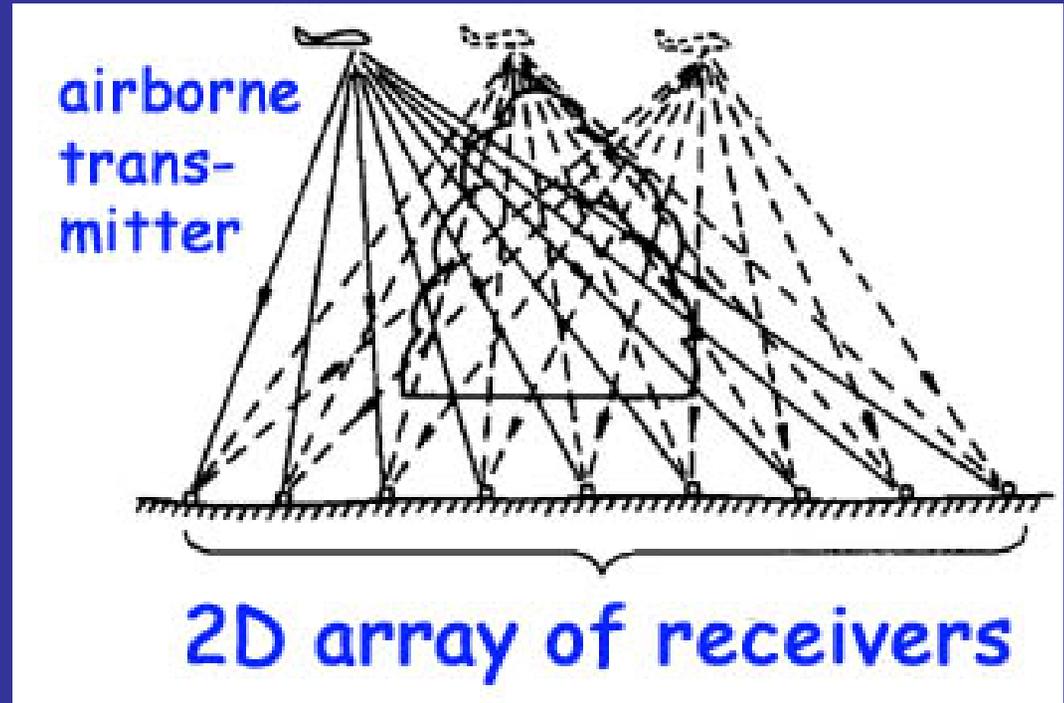
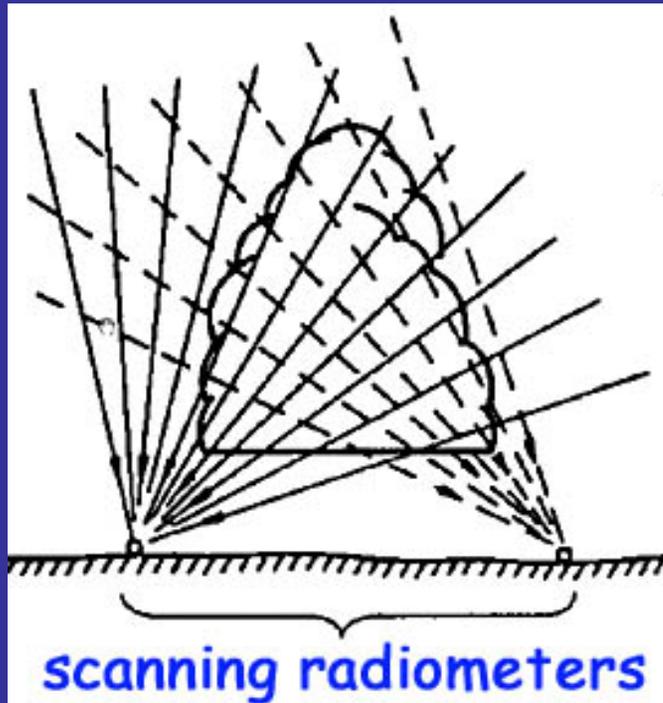
ARM's routine flights could be entrained to measure rad heat profile



tri-weekly aerosol flights since 2004

Now we will do the same for clouds!

Microwave cloud tomography: one way to get input needed for modeling rad heat profile



Warner's 1986 setup

A potential trial run: measure rad heat profile in forest canopies



Other things on the horizon

- Net flux instruments
- Small/light/cheap instruments
- Stratospheric balloon radiometers
- Improved statistical sorting of data
- Radiometersondes (spinning dropsondes?)

